

Towards Attribution of Hurricane Activity Changes

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1-GFDL; 2-Princeton/AOS; 3-U. Miami; 4-U. Wisc.-Milw.; 5-Old Dominion U.

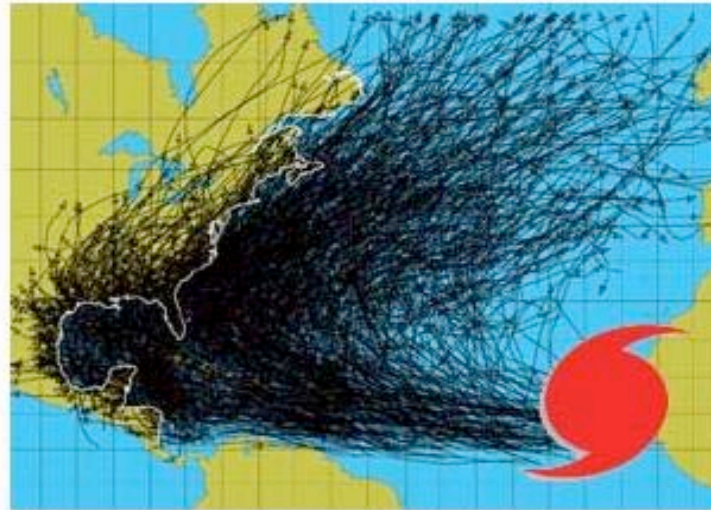
- Why hurricanes?
- What do we need? (relatively general)
 - Two part attribution: A -> B ; B -> Hurricanes
- Recent efforts at GFDL.

Why?

[NOAA Magazine](#) || [NOAA Home Page](#)

[Commerce Dept.](#)

NOAA ATTRIBUTES RECENT INCREASE IN HURRICANE ACTIVITY TO NATURALLY OCCURRING MULTI-DECADAL CLIMATE VARIABILITY



Nov. 29, 2005 — The nation is now wrapping up the 11th year of a new era of heightened [Atlantic hurricane activity](#). This era has been unfolding in the Atlantic since 1995, and is expected to continue for the next decade or perhaps longer. [NOAA](#) attributes this increased activity to natural occurring cycles in tropical climate patterns near the equator. These cycles, called “the tropical multi-decadal signal,” typically last several decades (20 to 30 years or even longer). As a result, the North Atlantic experiences alternating decades long (20 to 30

year periods or even longer) of above normal or below normal hurricane seasons. [NOAA](#) research shows that the tropical multi-decadal signal is causing the increased Atlantic hurricane activity since 1995, and is not related to greenhouse warming. [\(Click NOAA](#)

Research by NOAA scientists [..] and [..], currently in press with the *Journal of Climate*, describes the tropical multi-decadal signal and shows that it accounts for the entire inter-related set of conditions that controls hurricane activity for decades at a time."

ROSS GELBSPAN

Katrina's real name

The Boston Globe

By Ross Gelbspan | August 30, 2005

THE HURRICANE that struck Louisiana yesterday was nicknamed Katrina by the National Weather Service. Its real name is global warming.



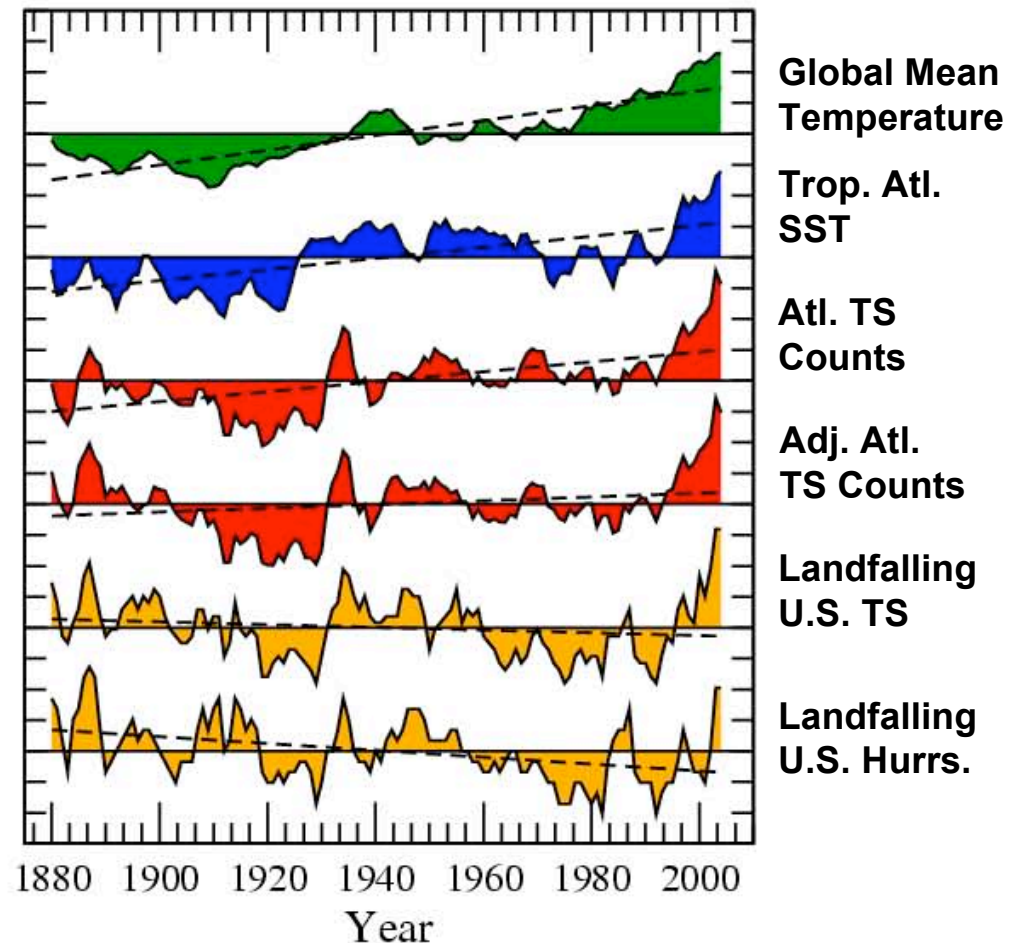
Requirements for attribution

Interconnected, complement/limit each other.

- Well-defined measure.
- Observations:
 - As homogeneous as possible
 - Uncertainty assessment
- Comprehensive dynamical models:
 - Capable of reproducing obs.
 - Play mix-and-match with forcings
- Understanding:
 - Theoretical framework
 - Idealized experiments

Measure of Activity

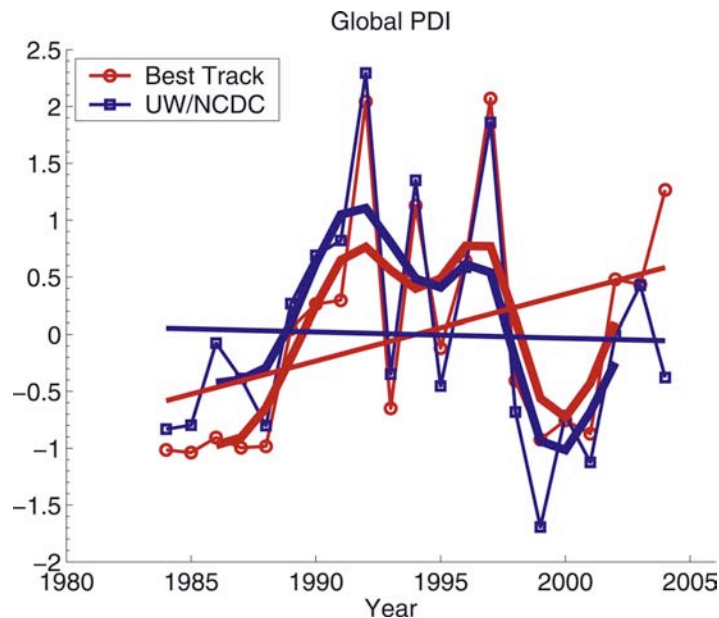
- Which measure?
 - Hurricane count
 - Landfalling storm count
 - Extremes in intensity
 - Shifts in mean intensity
 - Integrated intensity
- Must balance demand with current ability to attribute.
 - Obs, models and theory limit.
- How to communicate differences?



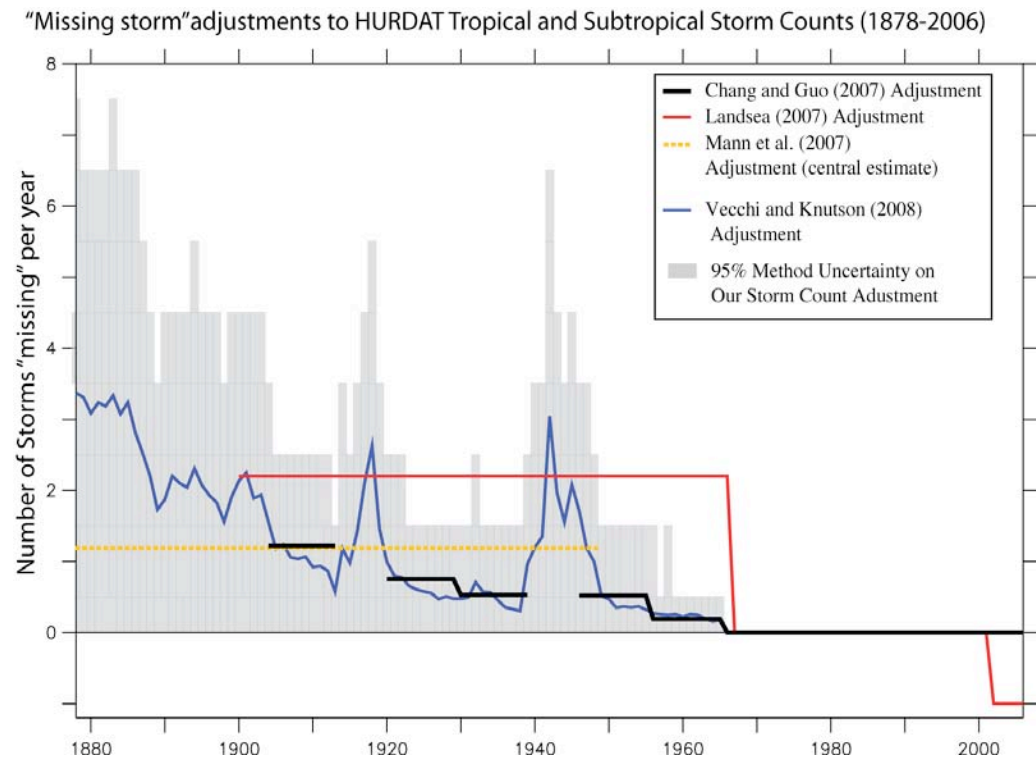
Vecchi and Knutson (2008, J. Clim.)

Observations

- Hurricane databases **NOT** built as climate data records.
- Efforts must continue to:
 - Identify issues
 - Homogenize when possible
 - Estimate uncertainty

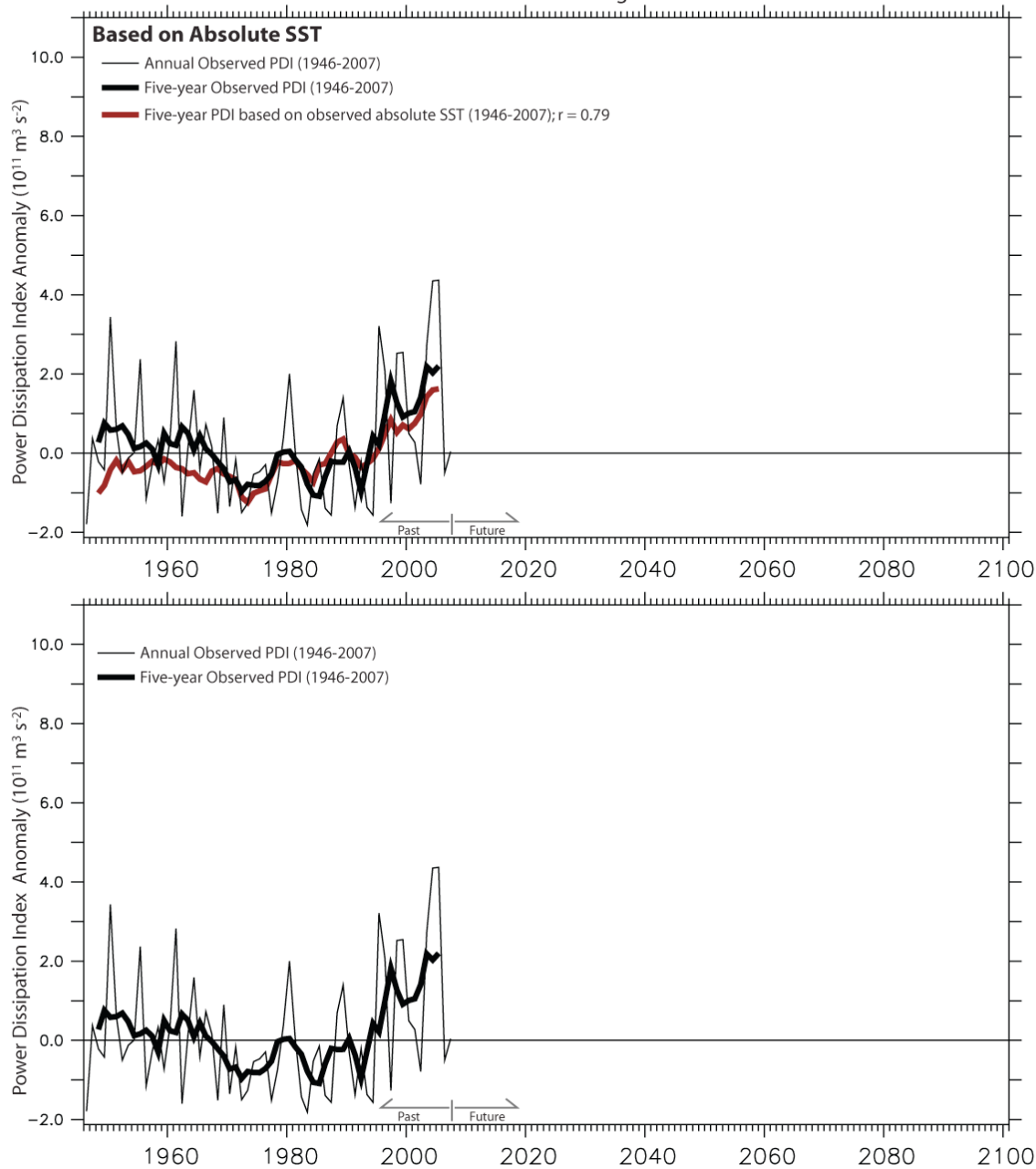


Kossin et al (2007, GRL)



Vecchi and Knutson(2008, J. Clim.)

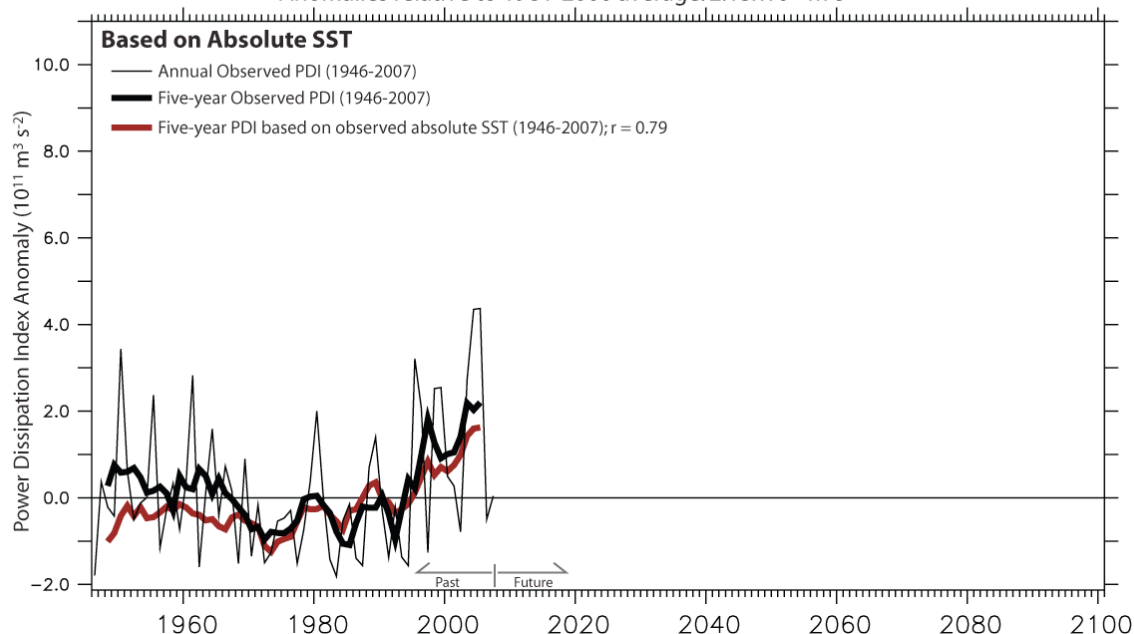
Atlantic Tropical Cyclone Power Dissipation Index Anomalies: Observed and Based on Sea Surface Temperature
 Anomalies relative to 1981-2000 average: $2.13 \times 10^{11} \text{ m}^3 \text{ s}^{-2}$



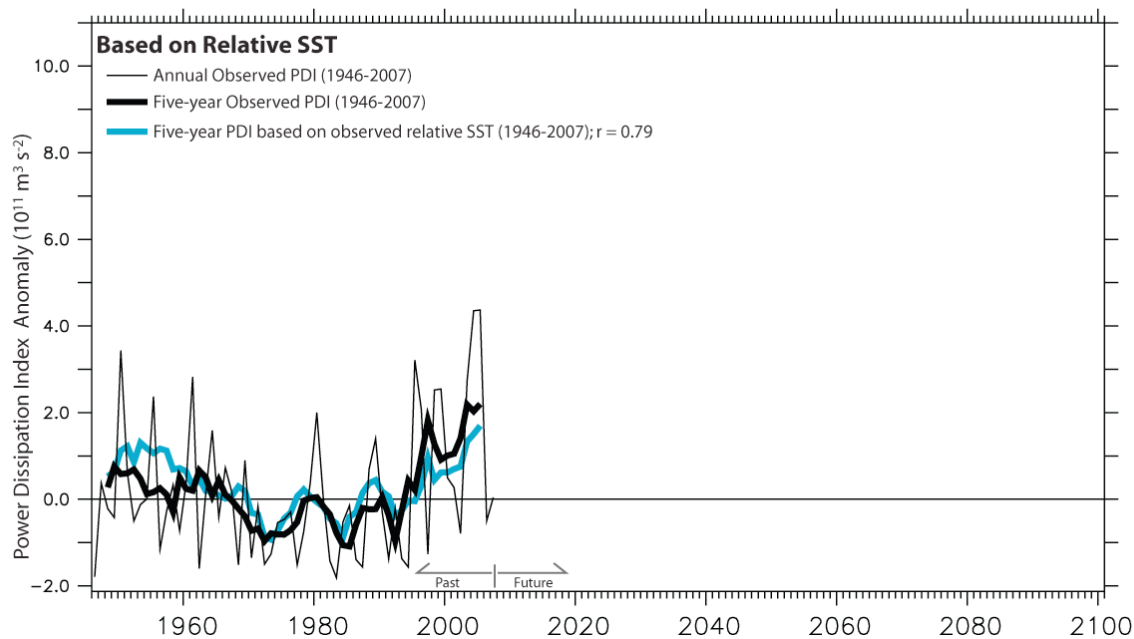
Observed Activity
Absolute MDR SST
 If causal, can attribute.

*Vecchi, Swanson and Soden
 (2008, Science)*

Atlantic Tropical Cyclone Power Dissipation Index Anomalies: Observed and Based on Sea Surface Temperature
Anomalies relative to 1981-2000 average: $2.13 \times 10^{11} \text{ m}^3 \text{ s}^{-2}$



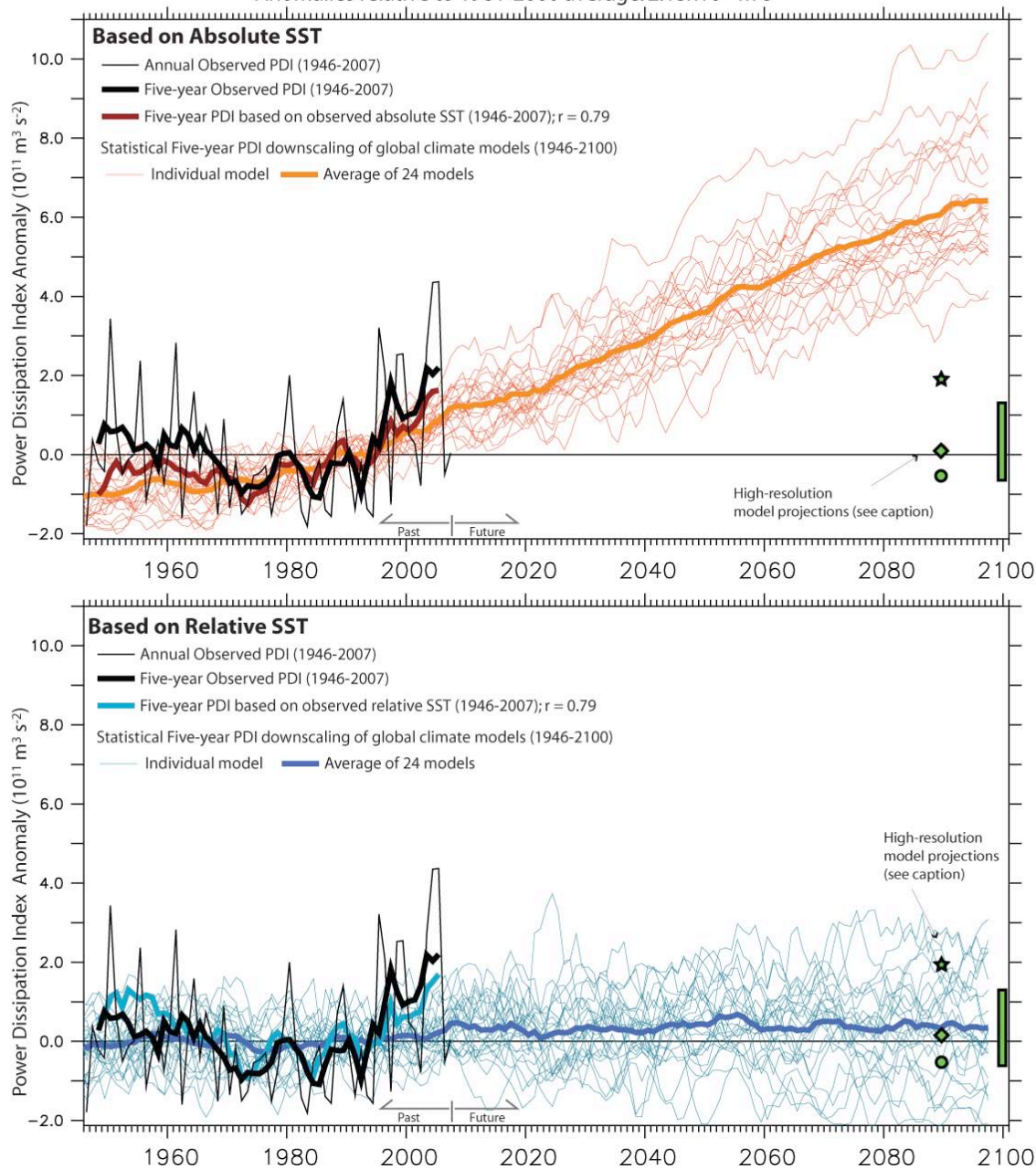
Observed Activity
Absolute MDR SST
If causal, can attribute.



Relative MDR SST
If causal, cannot attribute.

*Vecchi, Swanson and Soden
(2008, Science)*

Atlantic Tropical Cyclone Power Dissipation Index Anomalies: Observed and Based on Sea Surface Temperature
 Anomalies relative to 1981-2000 average: $2.13 \times 10^{11} \text{ m}^3 \text{ s}^{-2}$



Observed Activity
 Absolute SST
 Model Abs. SST

High-resolution
 model activity change

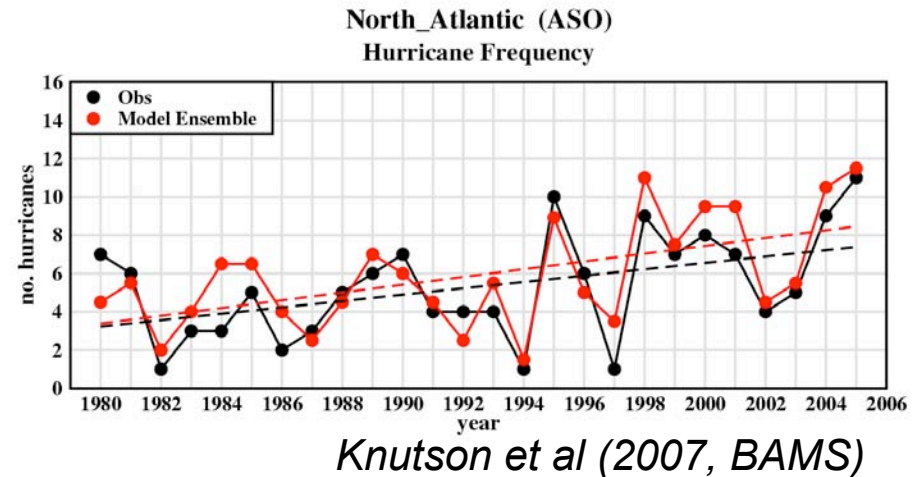
Emanuel et al (08), Knutson et al (08)
 Oouchi et al (06), Bengtsson et al (07)

Relative SST
 Model Rel. SST

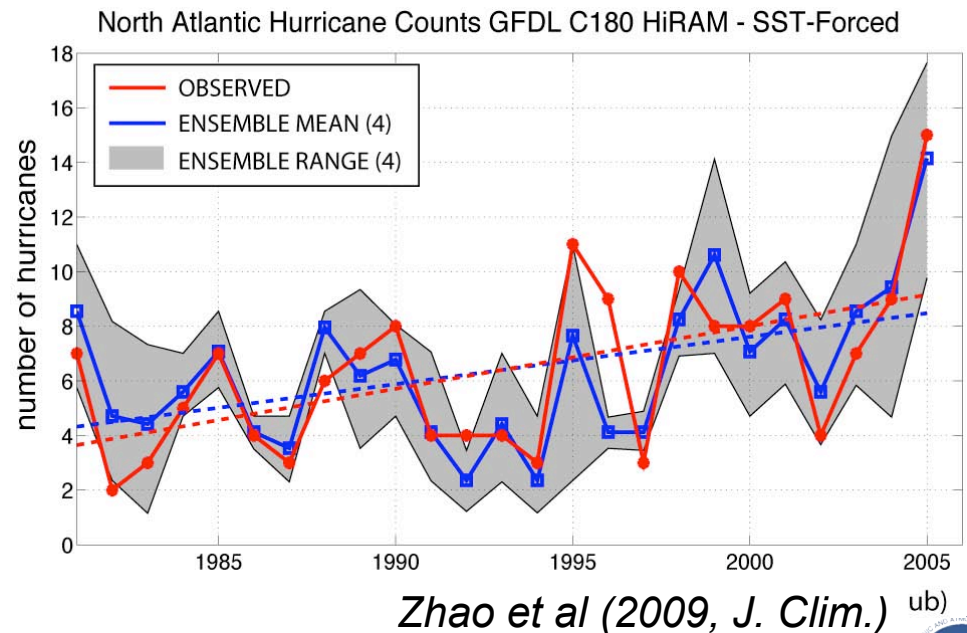
*Vecchi, Swanson and Soden
 (2008, Science)*

Comprehensive models

- Downscaling models using 3D forcing.
(Emanuel et al 2008, Knutson et al 2007, 2008,...)
- SST-forced AGCMs able to reproduce counts:
 - e.g. GFDL HiRAM (50km, 100km; Zhao et al 2009)
- Intensity requires refined tools.



SST-forced AGCM
Ensemble correlation = 0.83



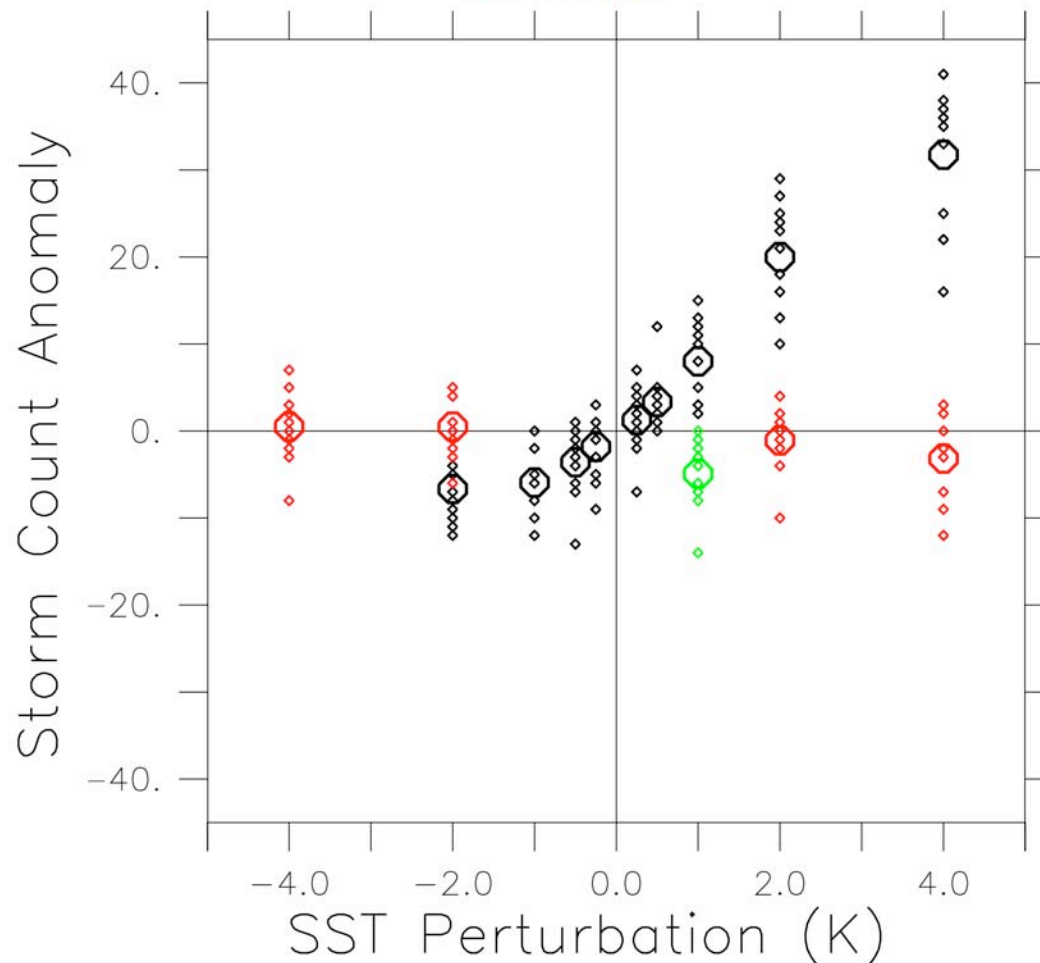
Understanding: what controls hurricanes?

- Potential Intensity theory exists:
 - *e.g.* Emanuel, Holland...
 - What are limitations?
- What is theory for genesis? Duration? ... why ~100 cyclones globally?
- Idealized forcing experiments with AGCMs:
 - Patterns of SSTA important
 - How model dependent?

North Atlantic Response to Idealized SST

Change in Annual NA Storms from Idealized SST:

NATL, GLO, EQU



Atlantic Forcing

Uniform Forcing

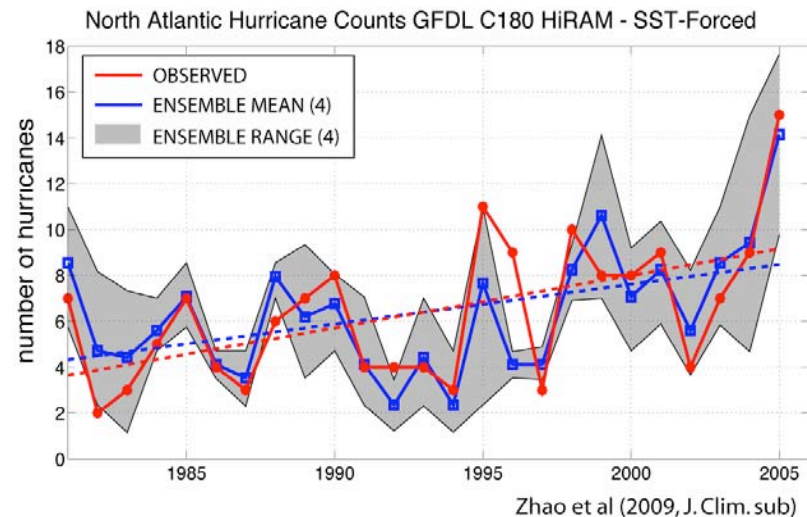
Near-equatorial
Forcing

Similar TS frequency
response to:
0.25° local warming
4° global cooling

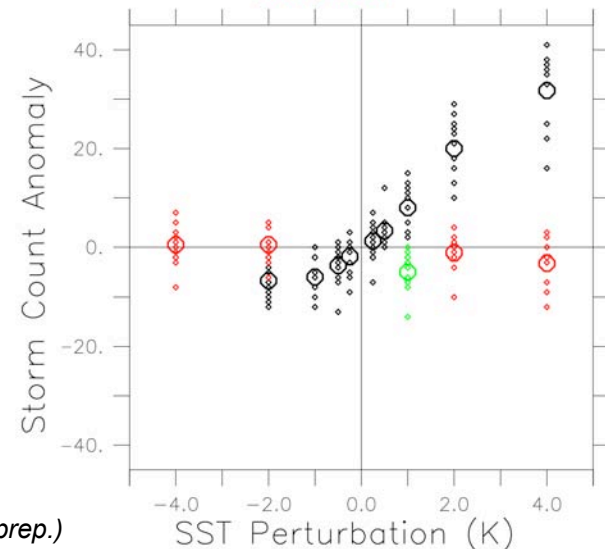
Vecchi et al (2009, in prep.)

Towards Atlantic TS Attribution

- Measure:
 - *Annual TS Counts*
- Observations:
 - *~25yr increase, but accounting for 'missed' storms increase not significant since late-19th Cy.*
- Comprehensive dynamical models:
 - *Recent increase can be forced by SSTs*
 - *Recent increase captured without global SSTA increase*
- Understanding:
 - *Need to attribute patterns of SSTA*
 - ***Theory for genesis lacking***



Change in Annual NA Storms from Idealized SST:
NATL, GLO, EQU

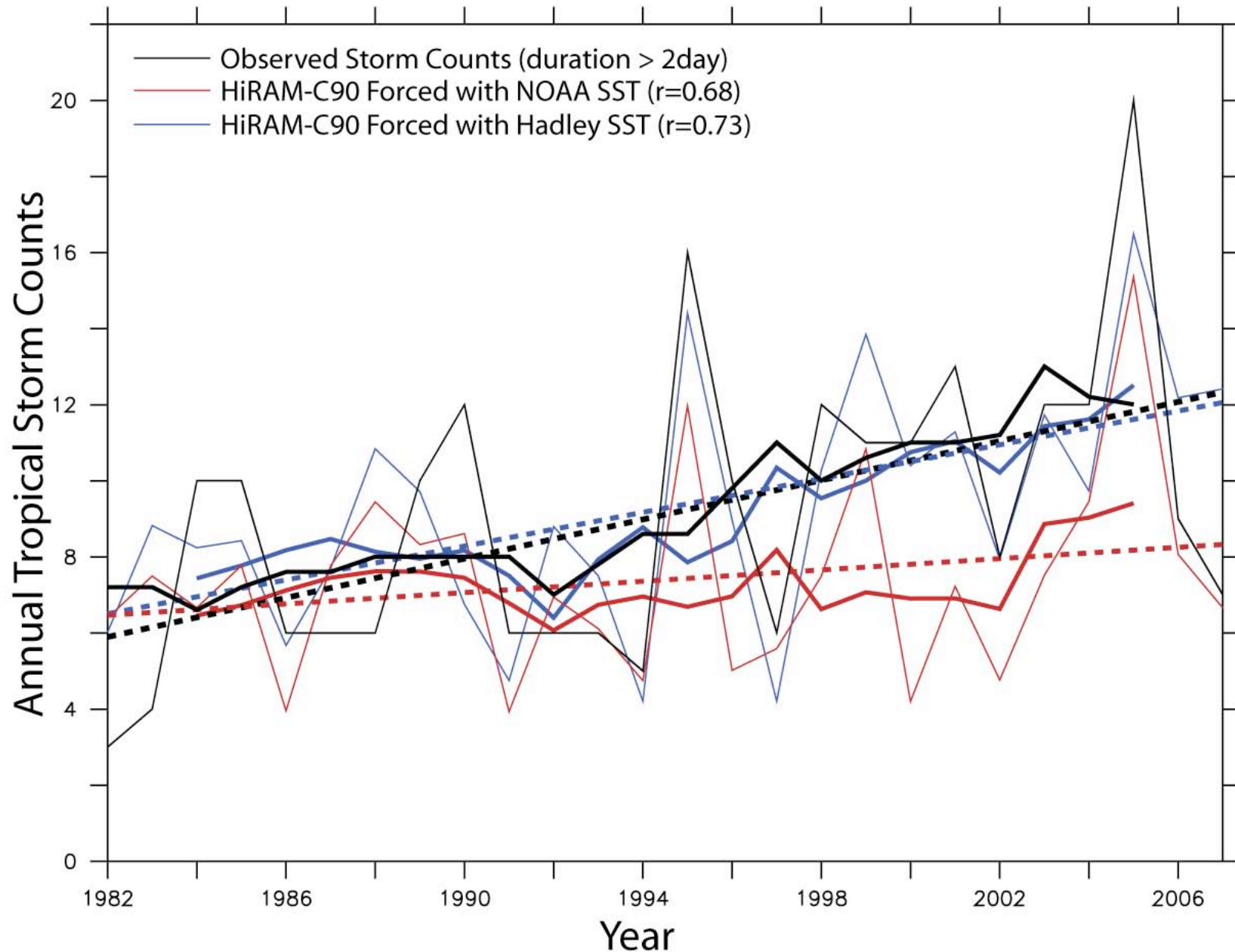


Vecchi et al (2009, in prep.)

EXTRA SLIDES

Perhaps for discussion.

GFDL HiRAM-C90 Atlantic Tropical Storm Counts



20-JAN-2009

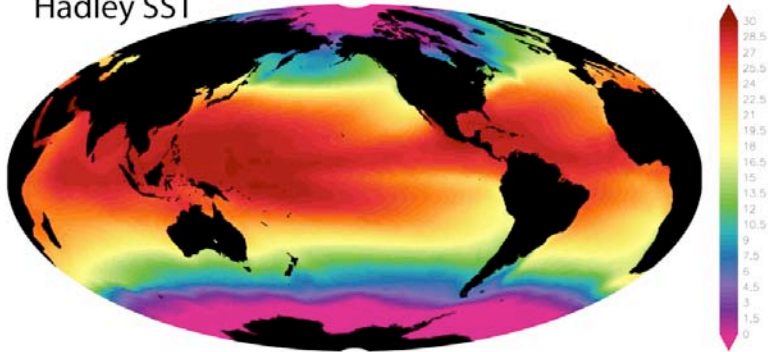
GABRIEL VECCHI, NOAA/GFDL, PRINCETON, NJ



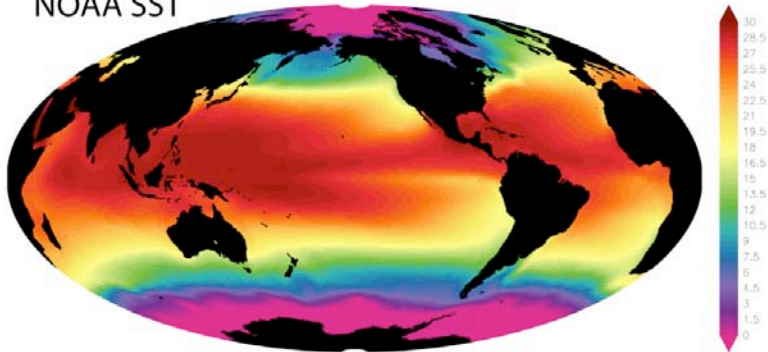
SST from two products

1982-2007 August-October Sea Surface Temperature ($^{\circ}\text{C}$)

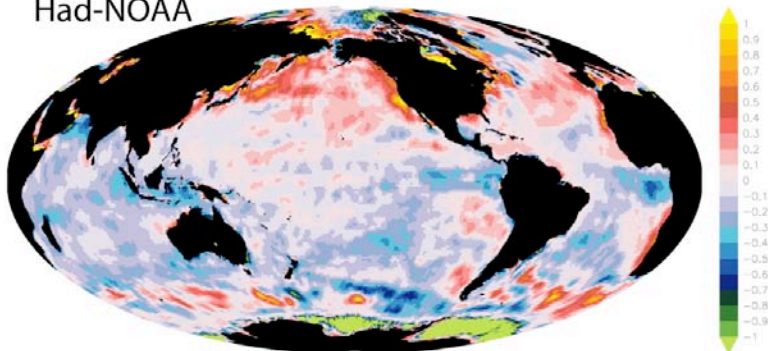
Hadley SST



NOAA SST

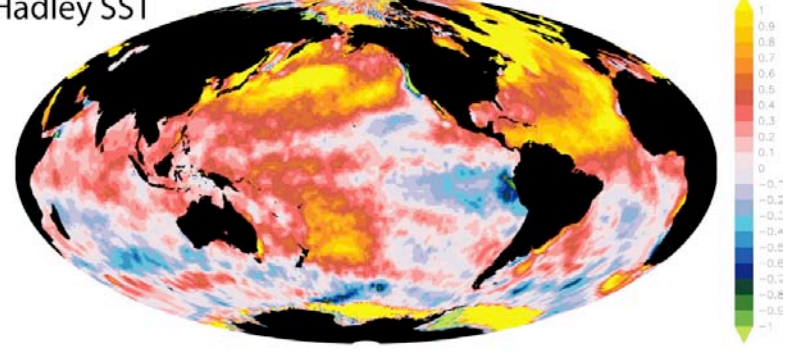


Had-NOAA

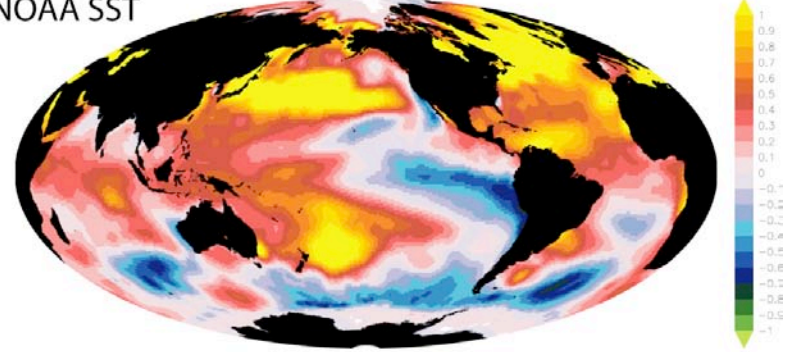


1982-2007 August-October SST Trends ($^{\circ}\text{C}$ per 25-years)

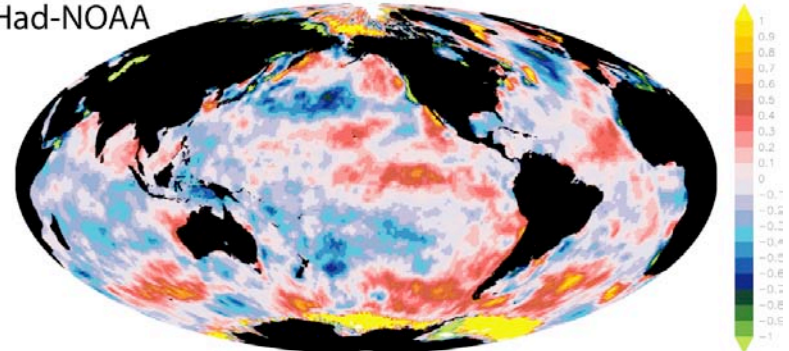
Hadley SST



NOAA SST



Had-NOAA

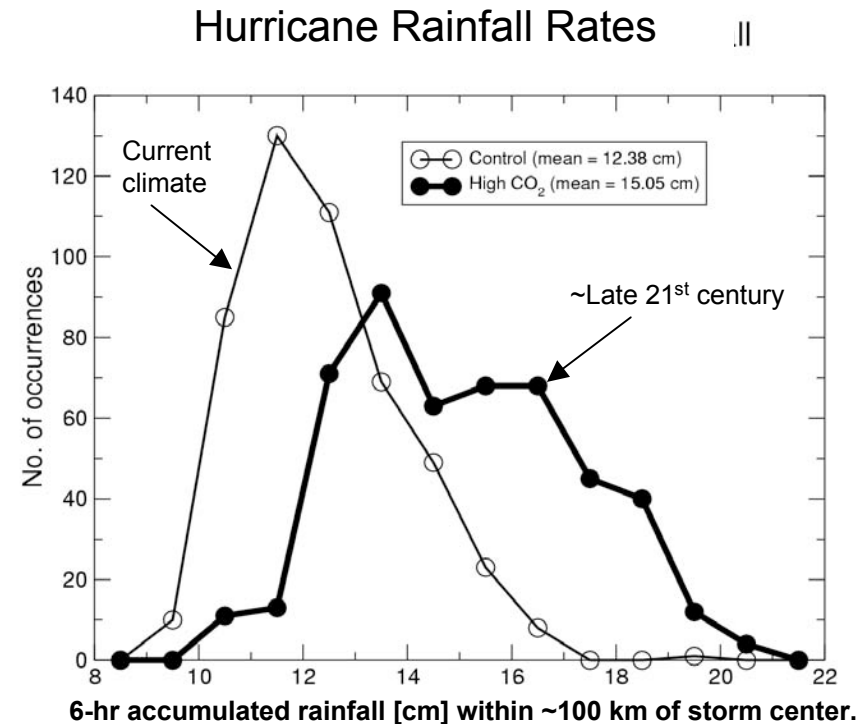
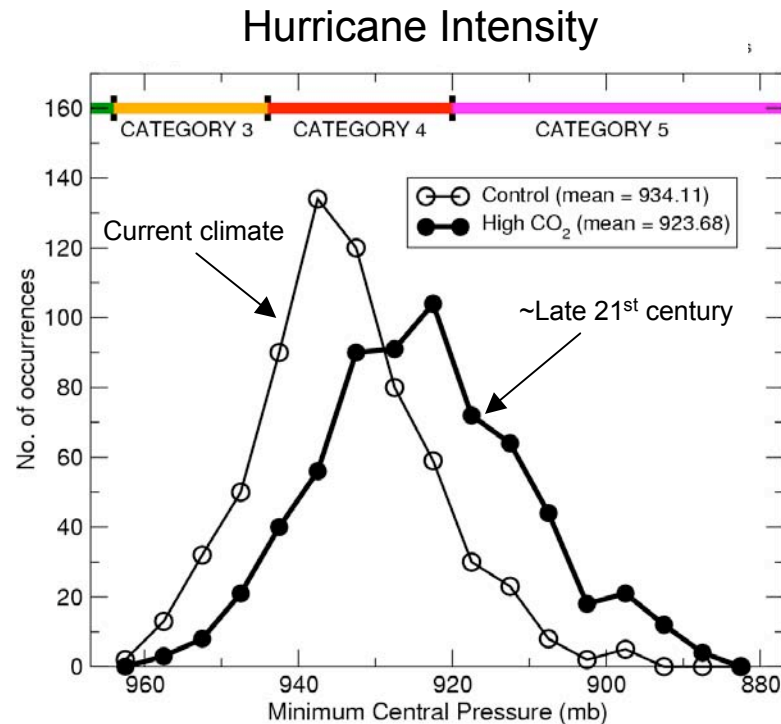


26-Jan-2009

Gabriel Vecchi, NOAA/GFDL, Princeton, NJ

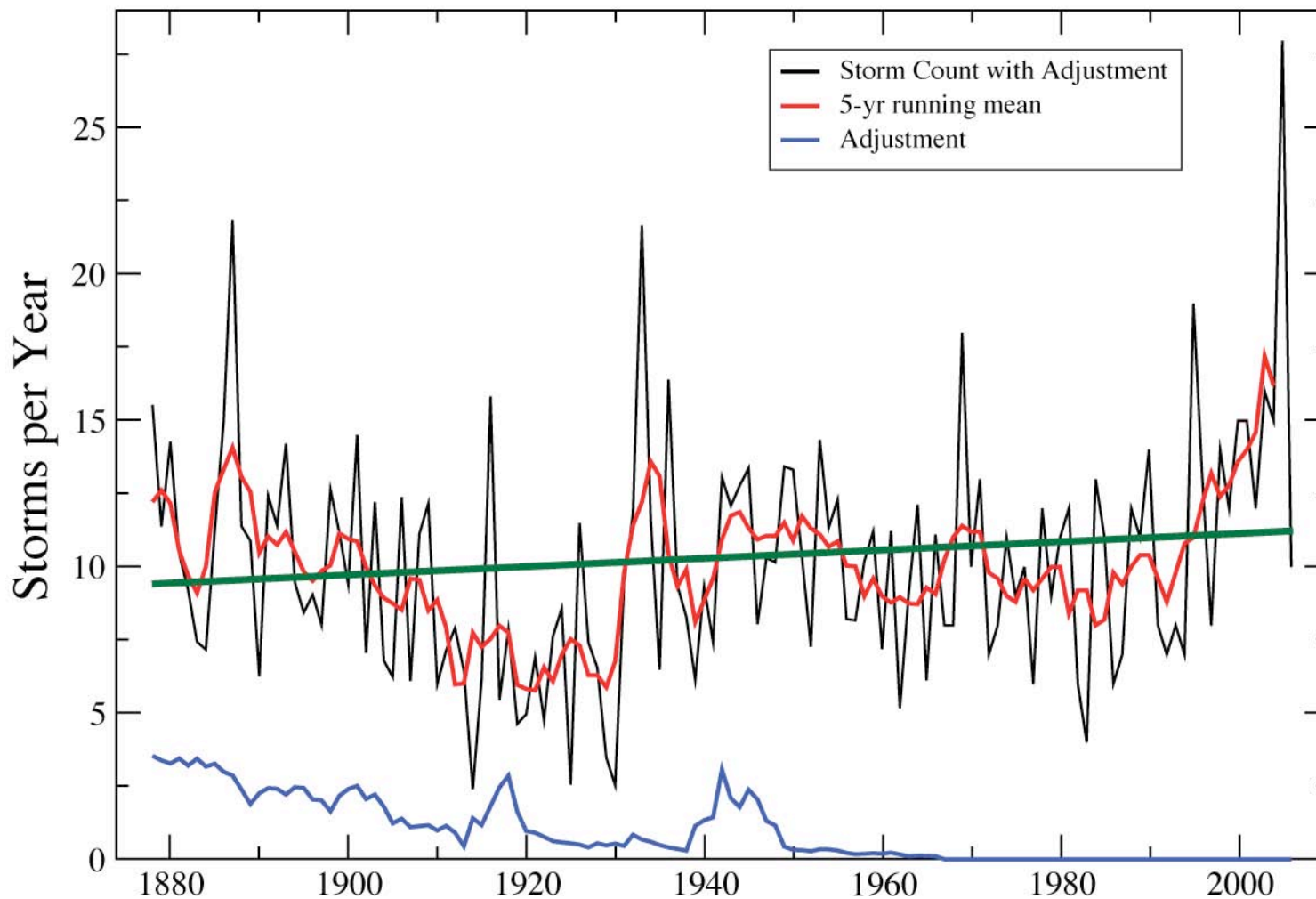


Hurricane models project increasing hurricane intensities and rainfall rates with greenhouse climate warming ...



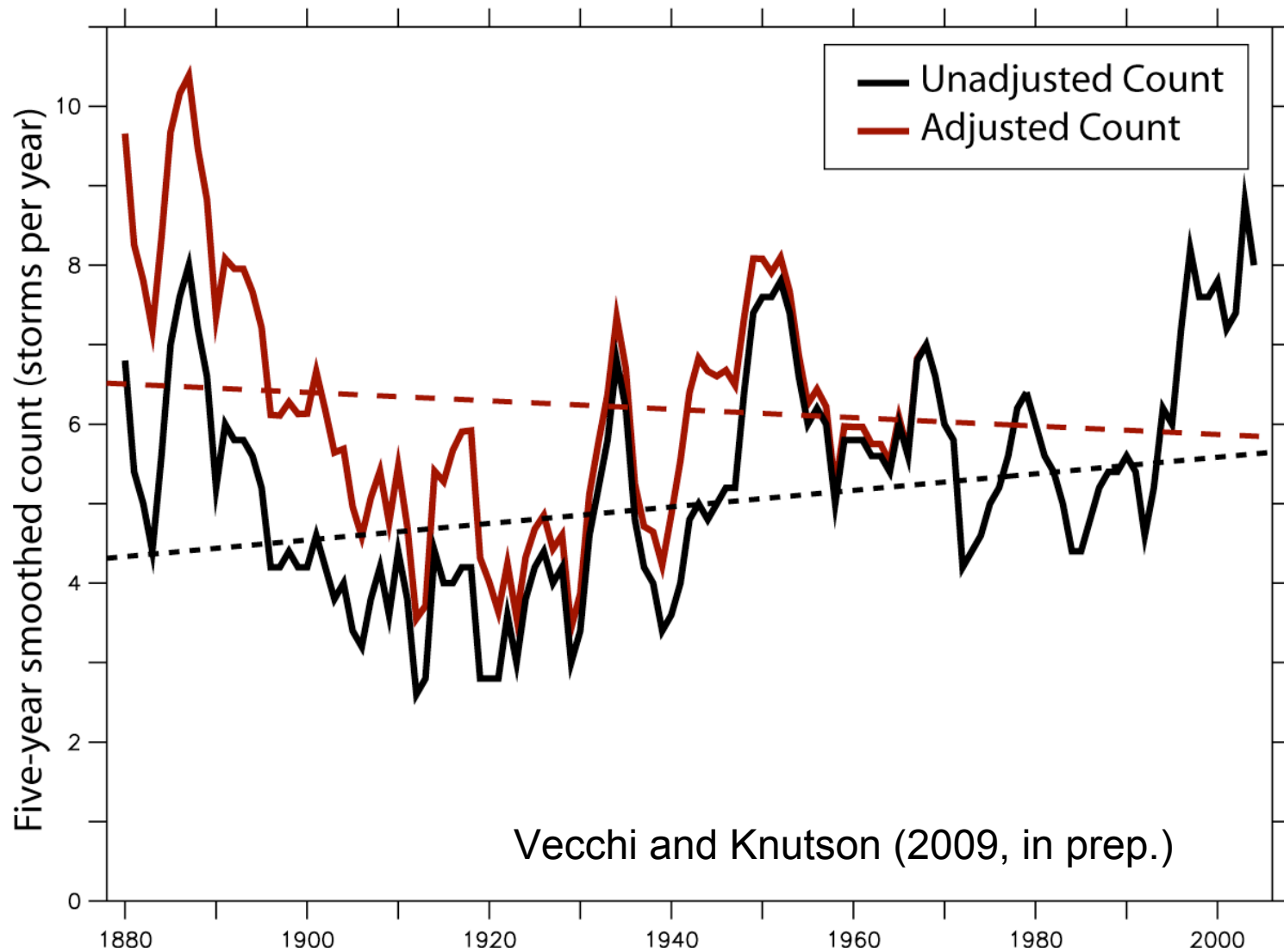
Sources: Knutson and Tuleya, *J. Climate*, 2004 (left);
Knutson and Tuleya, 2007; accepted for publication, Cambridge Univ Press (right).

Adjusted Atlantic Hurricanes, Tropical and Subtropical Storms



- Adjusted storm count trend since 1878 **not** distinct from “noise”
- Decadal swings **not** a simple “cycle”, either.

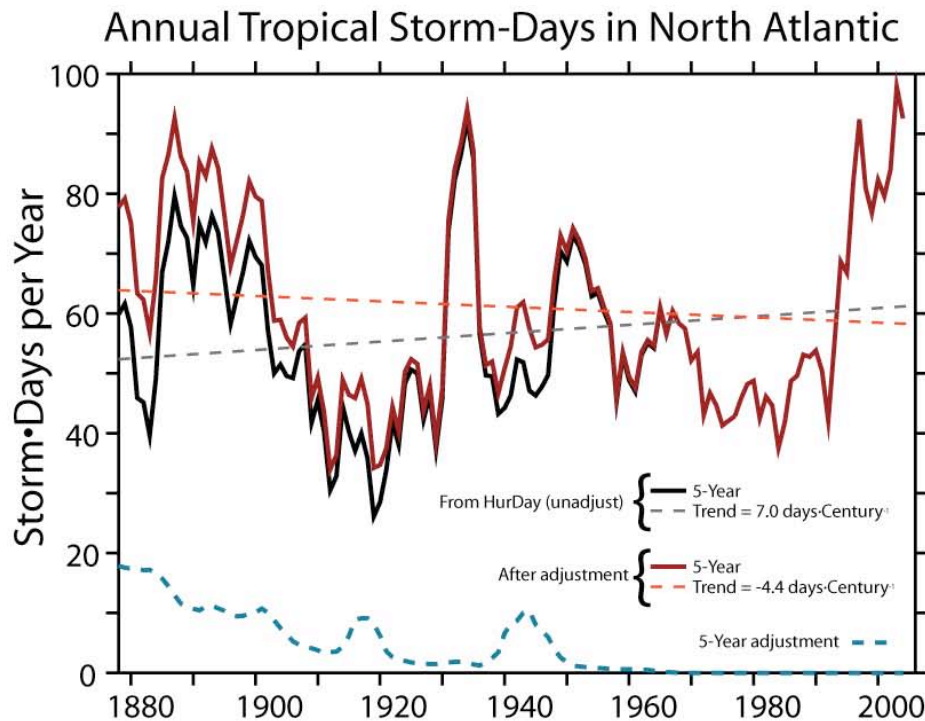
Count of Atlantic Hurricanes (Cat. 1-5)



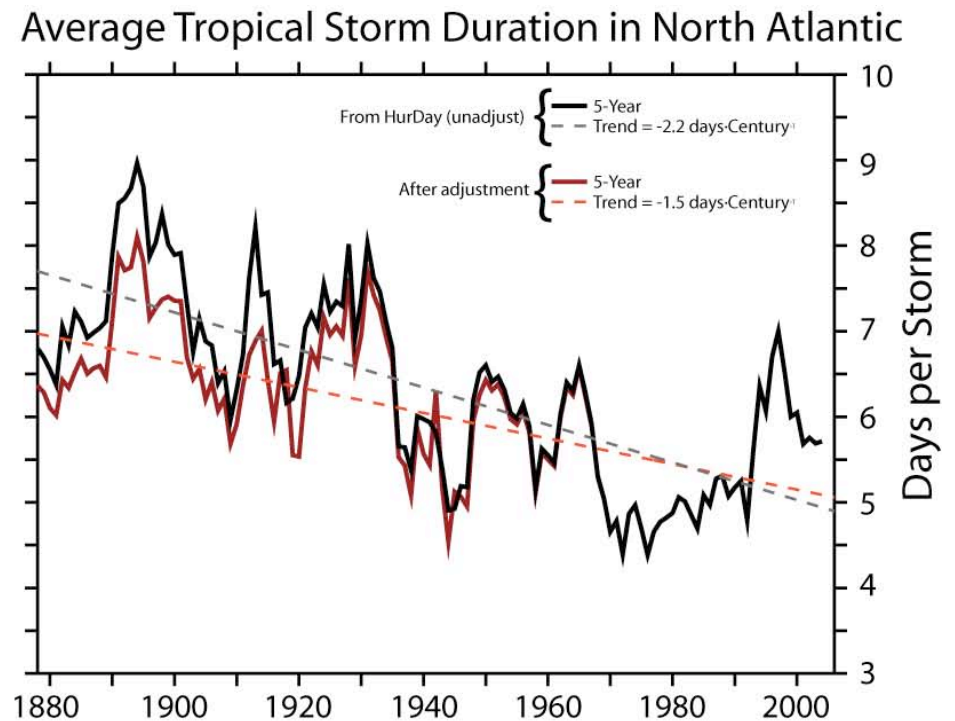
Vecchi and Knutson (2009, in prep.)

Adjustment changes sign of hurricane count trend

Other activity measures show no long-term increase



Landfalling count also shows no long-term trend.

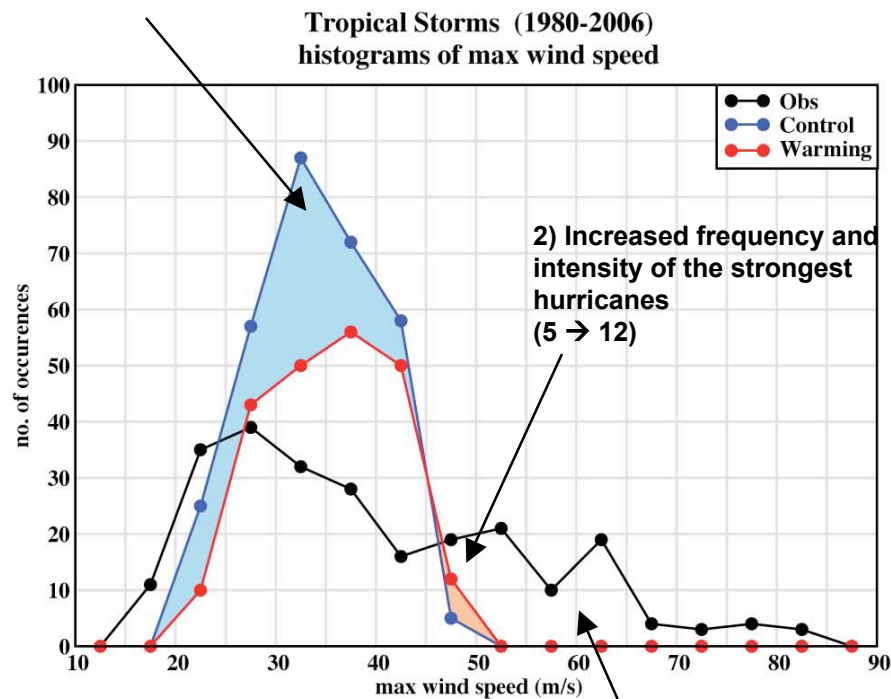


Average storm duration shows a decrease.
Real? Data problem?

Vecchi and Knutson (2008, J. Clim.)

The model provides projections of Atlantic hurricane and tropical storm *frequency* changes for late 21st century, downscaled from a multi-model ensemble climate change (IPCC A1B scenario):

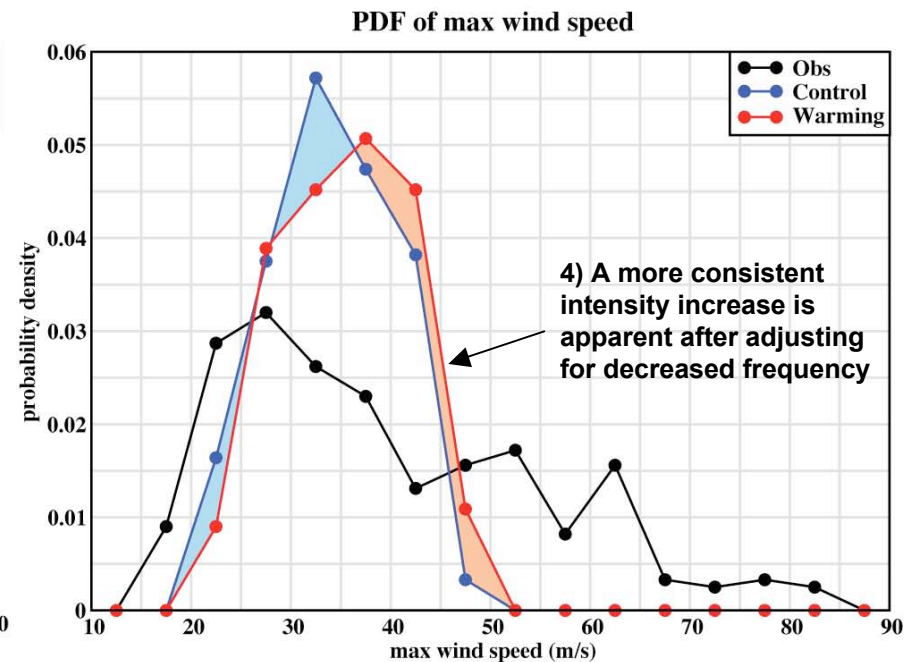
1) Decreased frequency of tropical storms (-27%) and hurricanes (-18%).



2) Increased frequency and intensity of the strongest hurricanes (5 → 12)

3) Caveat: this model does not simulate hurricanes as strong as those observed.

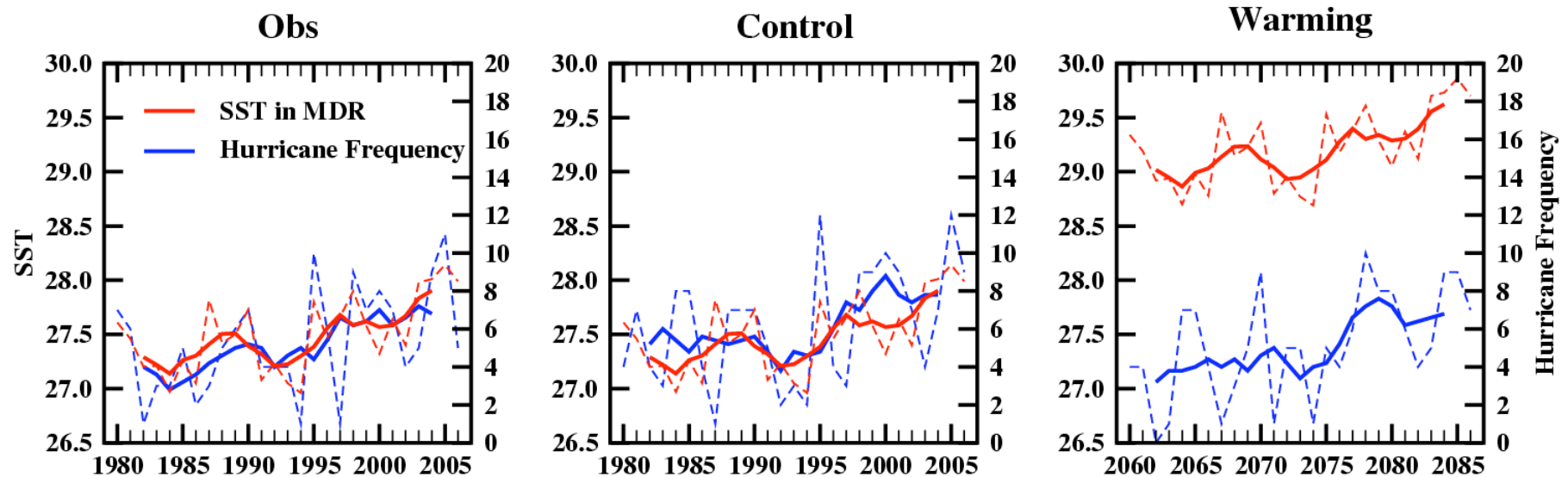
Storm Intensities (Normalized by frequency)



4) A more consistent intensity increase is apparent after adjusting for decreased frequency

Source: Knutson et al., 2008, Nature Geoscience.

The control model reproduces the observed close relationship between SST and hurricane frequency (1980-2006), but this statistical relationship does not hold for future human-caused warming in the model.



Hurricane frequency actually decreases by 18% in the warm climate case... although the model does not simulate hurricanes as intense as observed.

Lesson: Caution using correlations from the present climate to make future climate projections...

Source: Knutson et al., Nature Geoscience (2008).

Dependence on Climate Model: ZETAC model downscaling
(Warm minus Control)

Change in Storm Frequency - ZETAC 21st Century

Control: 11.1 /yr

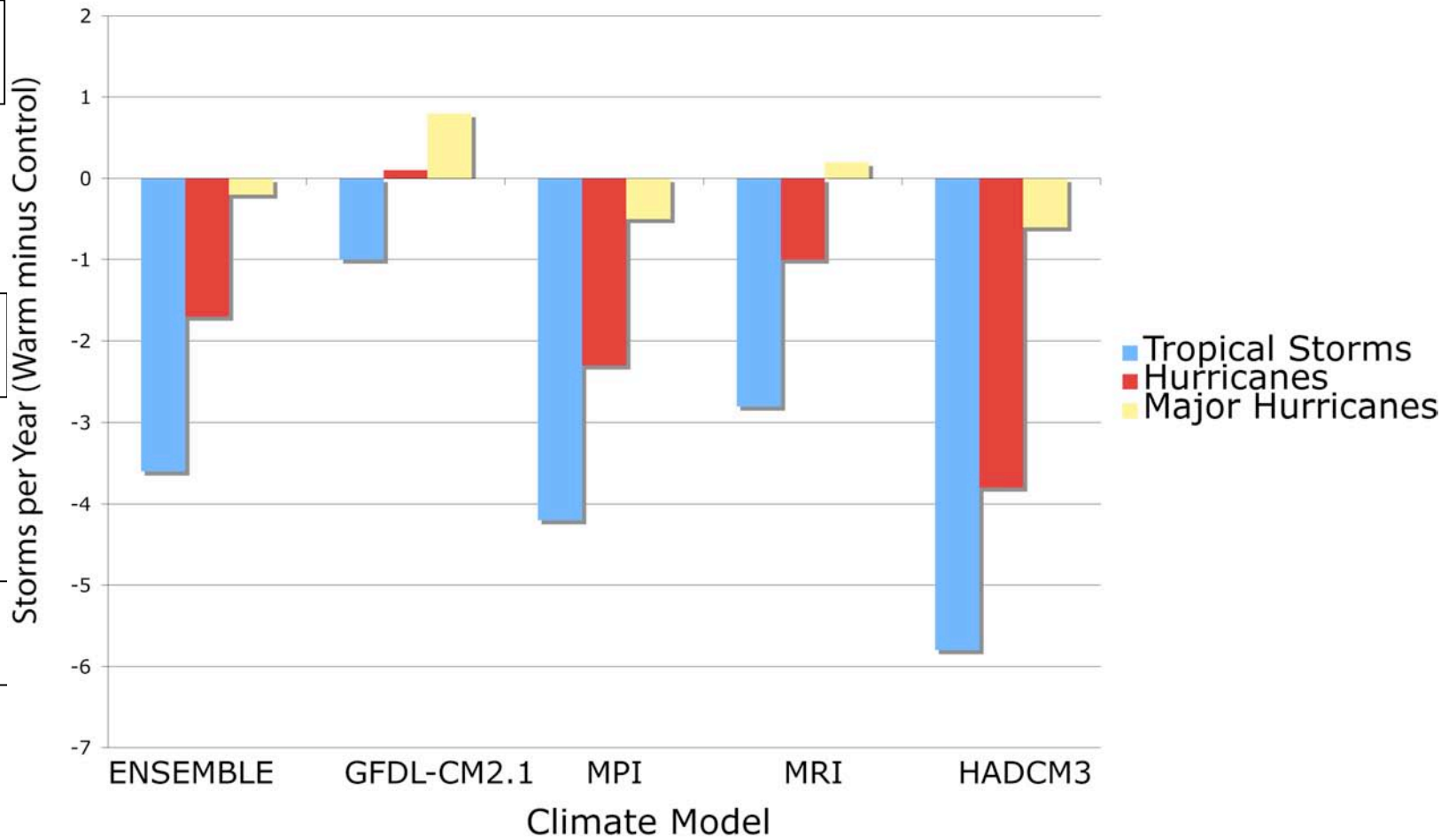
Tropical Storms:
Range: -9% to -52%
Ensemble: -20%

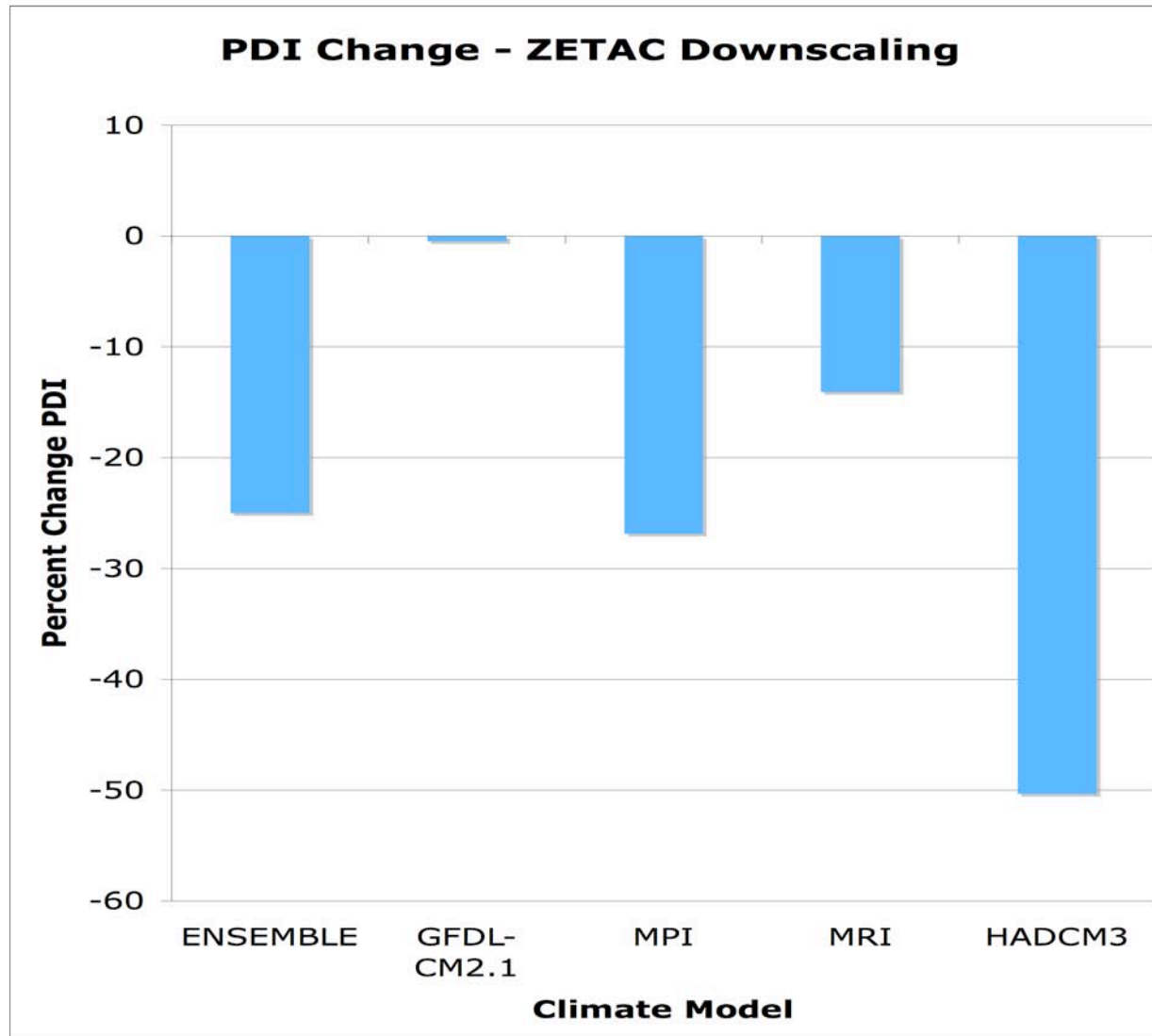
Control: 6.5 /yr

Hurricanes:
Range: +2% to -58%
Ensemble: -26%

Control: 1.4 /yr

Major Hurricanes:
Range: +57% to -43%
Ensemble: -14%





Power Dissipation (PDI) decreases as the reduced storm frequency dominates over increase in strength of strongest storms.

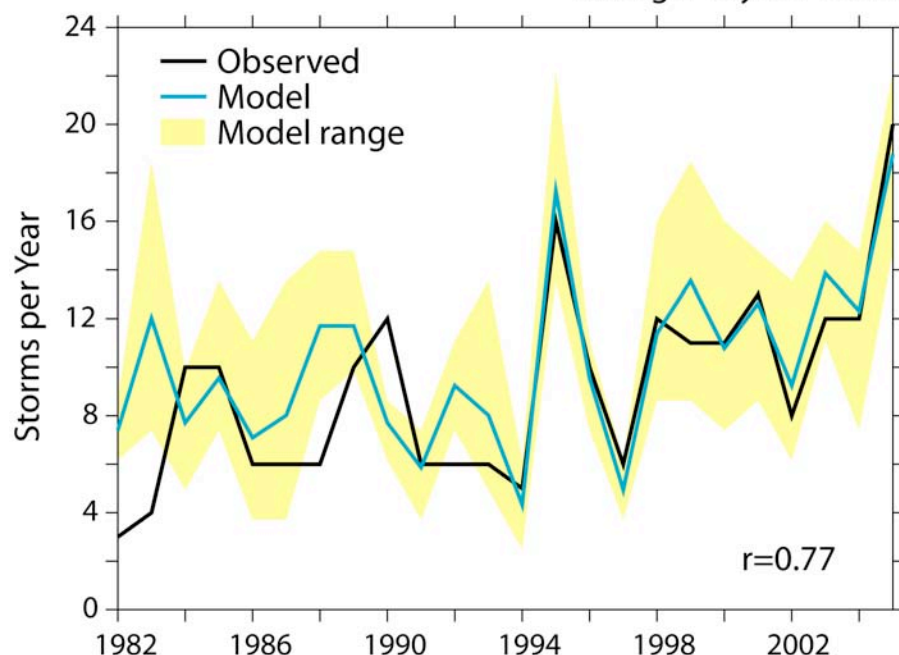
GFDL C-X HiRAM GCMs

Family of global atmospheric models designed for better-representing tropical cyclone frequency. **C90 - 1°**, C180=1/2°, C360=1/4°, C720=1/8°

Ref. Ming Zhao, S-J Lin and Isaac Held.

North Atlantic Tropical Storms*

*lasting 2 days or more



Adapted from AM2 with:

- Deep convection scheme adapted from Bretherton, McCaa and Grenier (MWR, 2004)
- Cubed sphere dynamical core
- Changes to parameterizations of cloud microphysics
- C90 Atm. resolution of 1°x1°

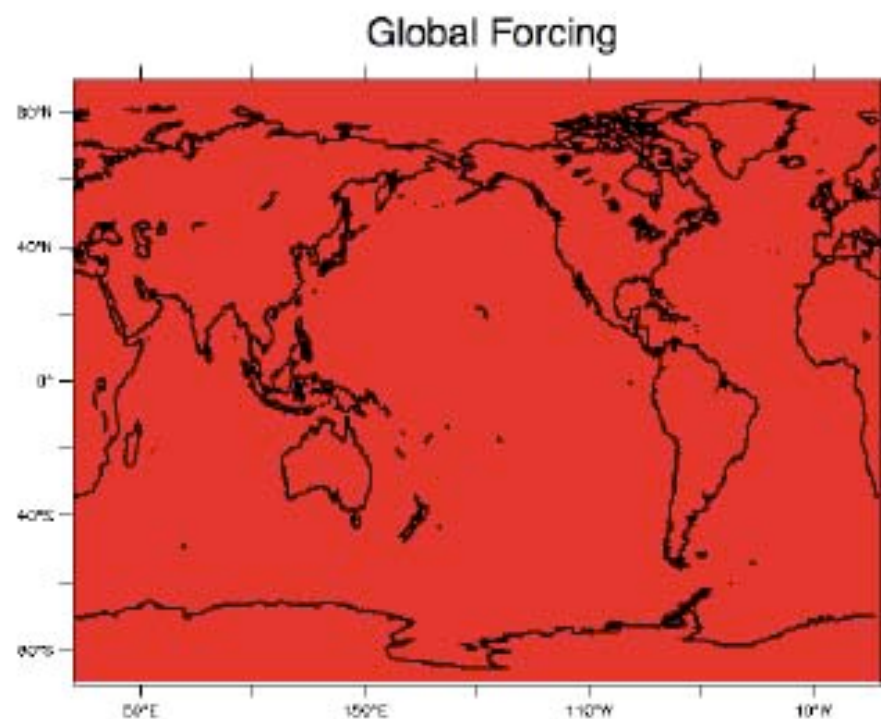
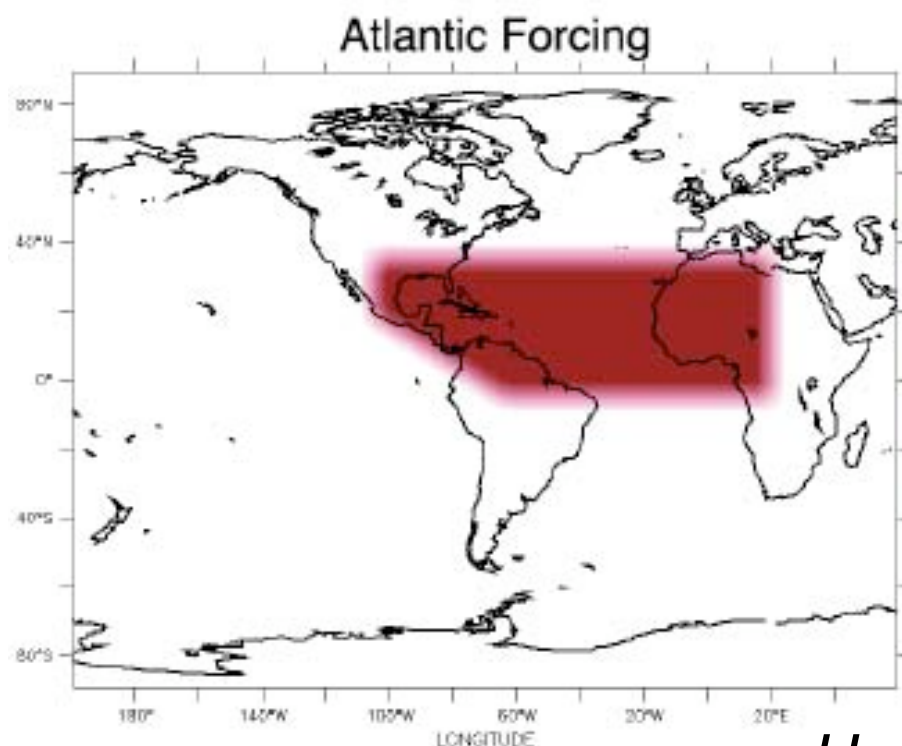
Explore C90 Model

Unpublished: do not quote or cite

Idealized Forcing Experiments

If local SST the dominant control, as opposed to relative SST:

- Similar Atlantic Response to Atlantic and Uniform F'cing
- Little Pacific Response to Atlantic compared to Uniform

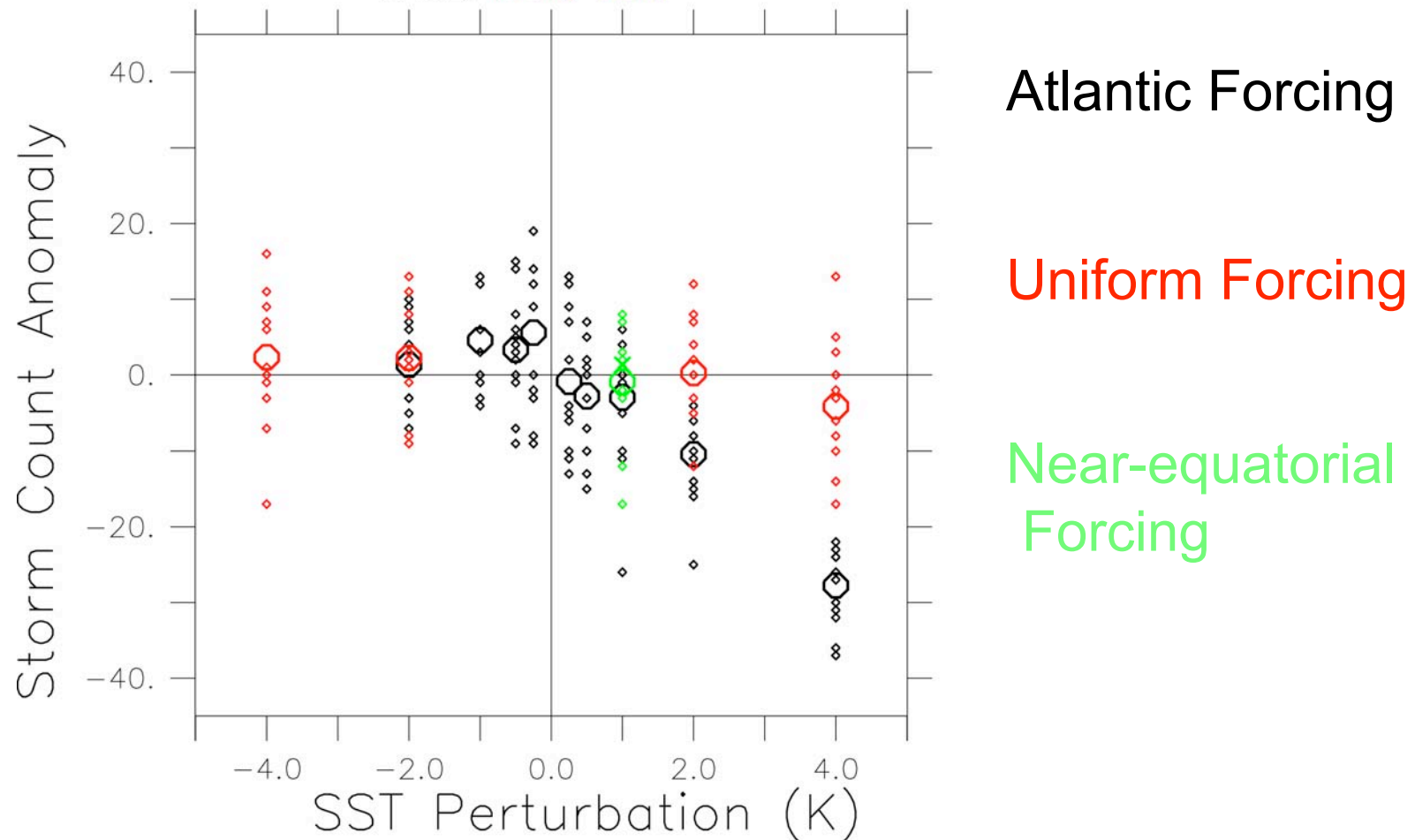


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Response in Northwest Pacific

Change in Annual WP Storms from Idealized SST:

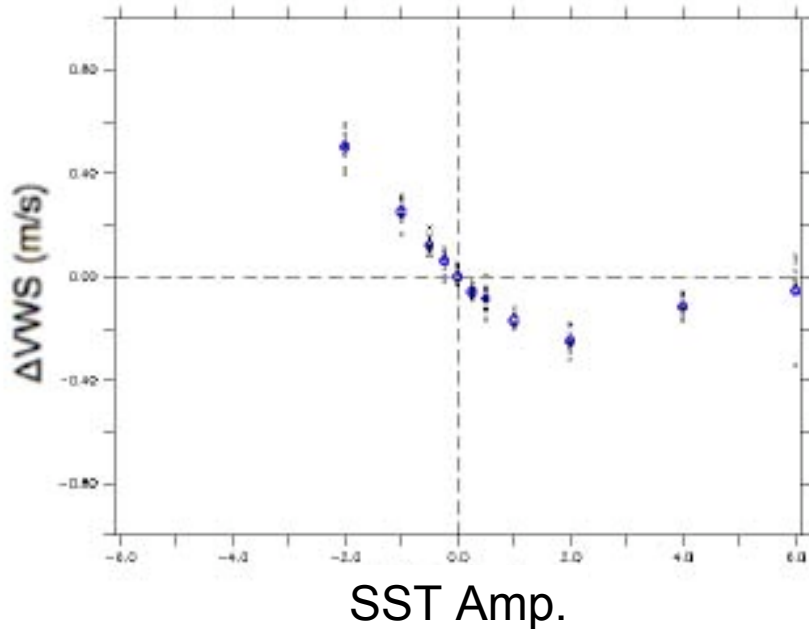
NATL, GLO, EQU



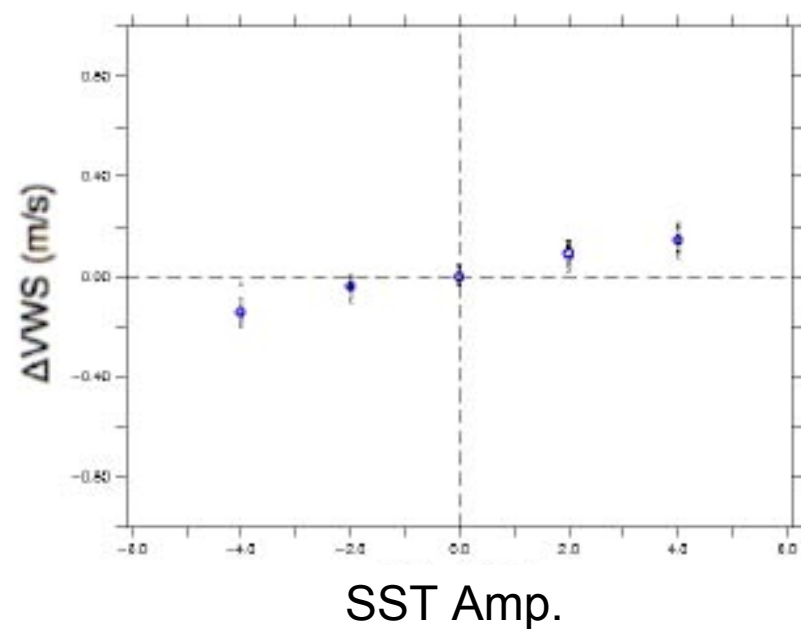
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Atlantic Vertical Wind Shear Changes

Atlantic SST Forcing



Global SST Forcing



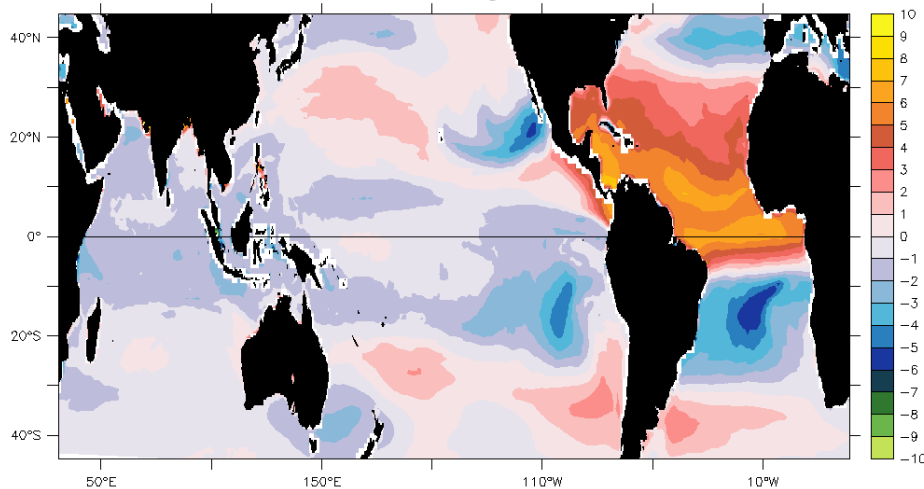
Localized warming in Atlantic decreases wind shear:
“storm friendly”

Uniform warming increases wind shear:
“storm hostile”

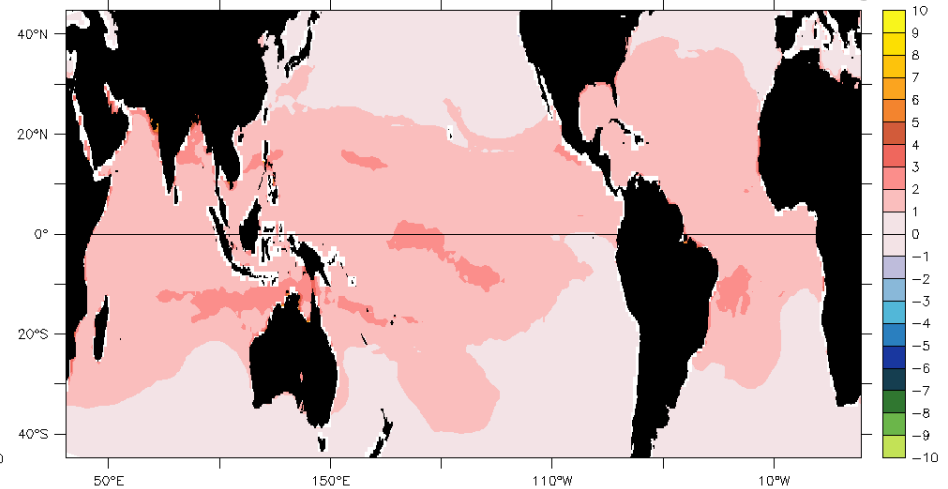
Potential Intensity Change

m/s per degree warming

Atlantic forcing



Uniform forcing



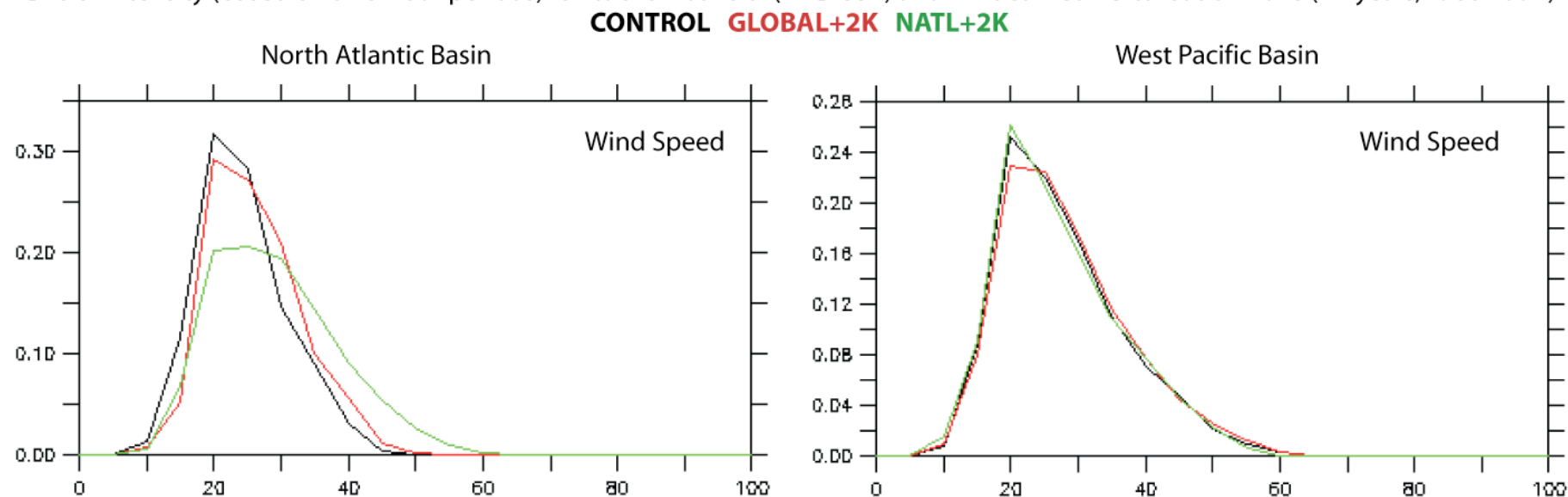
- In C90 HiRAM:
 - Localized SST forcing has large local impact on PI.
 - Remote decreases - consistent with Vecchi and Soden (2007, Nature)
 - Uniform SST forcing has smaller impact on PI.
- Change in PI does not explain change in Atlantic frequency.

Unpublished: do not quote or cite

Impact on Intensity*

*Modest C90 model resolution limits confidence in intensity results

PDFs of Intensity (based on all 6-hour periods) for C90L32 Control (HADISST) and 2K Idealized Perturbation Runs (12-years, 1980-1991)



Uniform warming: modest increase in intensity.

Localized Atlantic warming:

large intensification in Atlantic
modest weakening in Pacific

Unpublished: do not quote or cite

Density of storm tracks affected by adjustment

Trend in Storm Track Density 1878-2006

from Vecchi and Knutson
(2007, J. Climate)

